ICES 89

C.M.1989/H:23 Ref.L
Pelagic Committee

THE EGG PRODUCTION METHOD APPLIED TO THE SPAWNING BIOMASS ESTIMATION OF SARDINE (Sardina pilchardus, Walb.) IN THE NORTH-ATLANTIC SPANISH COASTS.

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ABSTRACT

During the month of April on to May, 1988, an Egg Production Method Cruise was carried out with the purpose of evaluating the spawning biomass of the sardine (Sardina pilchardus, Walb.) from the Galician and Cantabrian coasts of Spain. This cruise was coordinated with the acoustical evaluation of this stock on board the R/V Cornide de Saavedra.

The area covered extends from the Spanish-Portuguese border (41°55'N) to the Spanish-French border (1°58'W). Vertical plankton tows were realized in 524 stations distributed on continental shelf and slope waters in a 6 x 6 mile grid and a 6 x 3 mile grid in areas of more intense spawning, in order to estimate the daily egg production parameter.

A total of 44 epipelagic trawls were effectuated in order to estimate the biological parameter relative to the adult population, that is, average female weight, batch fecundity, spawning fraction and sex ratio.

The survey area was post-stratified into three regions and the spawning biomass was estimated for each region. The sum of the three spawning biomass estimates was the total spawning biomass for the survey area. Three regions were established by

differentiated adult parameters, such as, average female weight in conjunction with the considered acoustical divisions. These regions correspond to the Galician coast (I), the western Cantabrian area (II) and the eastern sector of the Cantabrian coast (III).

The biomass estimates with their respective coefficient of variation of each region were,

	Galicia I	W Cant. II	E Cant. III	Total Areas
Spawning Biomass(B)	134,195	33,503	12,467	180,165
c.v.	0.66	0.30	0.56	0.50

Maximum biomass estimates occurr in the Galician shelf, although the stock is mainly concentrated in the northern sector of Galicia and the westernmost part of the Cantabric shelf. Biomass estimates decrease towards the east. This trend is similar to the biomass estimate from acoustic survey, although the differences in estimates differ aproximately 110.000MT.

INTRODUCTION

Fisheries assessment and management on the iberic pilchard (Sardina pilchardus, Walb) from the north-atlantic coasts have been used in two stock evaluation methods: VPA (since 1976) and acoustic survey evaluations (since 1983). Within the framework of a SARP project on sardine recruitment variability, another stock estimation procedure, EPM, was introduced; that is, the Egg Production Method (Lasker, R., ed., 1985). EPM has been used for fisheries assesment purposes and for the respective year class spawning biomass estimates of northern anchovy, Engraulis mordax, from the coasts of California (Picquelle & Hewitt, 1983; Picquelle & Hewitt, 1984; Bindman, 1985).It has also been implemented on other related species, such as, the Peruvian anchovy, Engraulis ringens (Santander et al., 1984); on the southern Benguela anchovy, Engraulis capensis (Armstrong et al., 1988). In the ICES area, efforts are being made to apply fishery independent estimates such as the EPM. Alheit, J. (1985) described briefly the method at the ICES 73rd Statutory Meeting. Santiago et al., (1989) applied EPM to the Bay of Biscay anchovy.

The purpose of this paper is to present the first experience of EPM on the Iberic sardine (Sardina pilchardus). An EPM cruise combined simultaneously with an Acoustic survey was carried out from March 29 to May 6, 1988, which covered the whole of the Galician and Cantabrian waters. This survey was coordinated with another EPM survey along the Portuguese coast on the same species (Cunha et al., 1988).

To conduct a successful EPM cruise, the following information is required: the spatial and/or temporal distribution of the planktonic stages of pilchard, the spawning season intensity and the delimitation of the spawning areas (Smith & Hewitt, 1985).

The peak spawning period (from March to April) coincides with the survey's duration (Dicenta, 1984; Solá, 1987; Lago et al. 1988; Pérez et al., 1985), which was also supported by a monthly sampling scheme (from 1987 to 1989) in the Vigo, La Coruña and Santander locations and the spawning area was investigated during a 1987 survey (García et al., 1988).

The knowledge of the reproductive biology of pilchard and the correct histological techniques are also essential for obtaining accurate estimates of the reproductive parameters.

METHODS

Survey description

The combined EPM and Acoustic survey of 1988 (MPH-SARACUS 0488) was conducted aboard the R/V Cornide de Saavedra from March 29 on to May 6. The cruise began — in the southern area of the Galician shelf next to the Spanish-Portuguese border (41°55'N) and ended in the transect close to the Spanish-French border (1°58'W) (Fig.1).

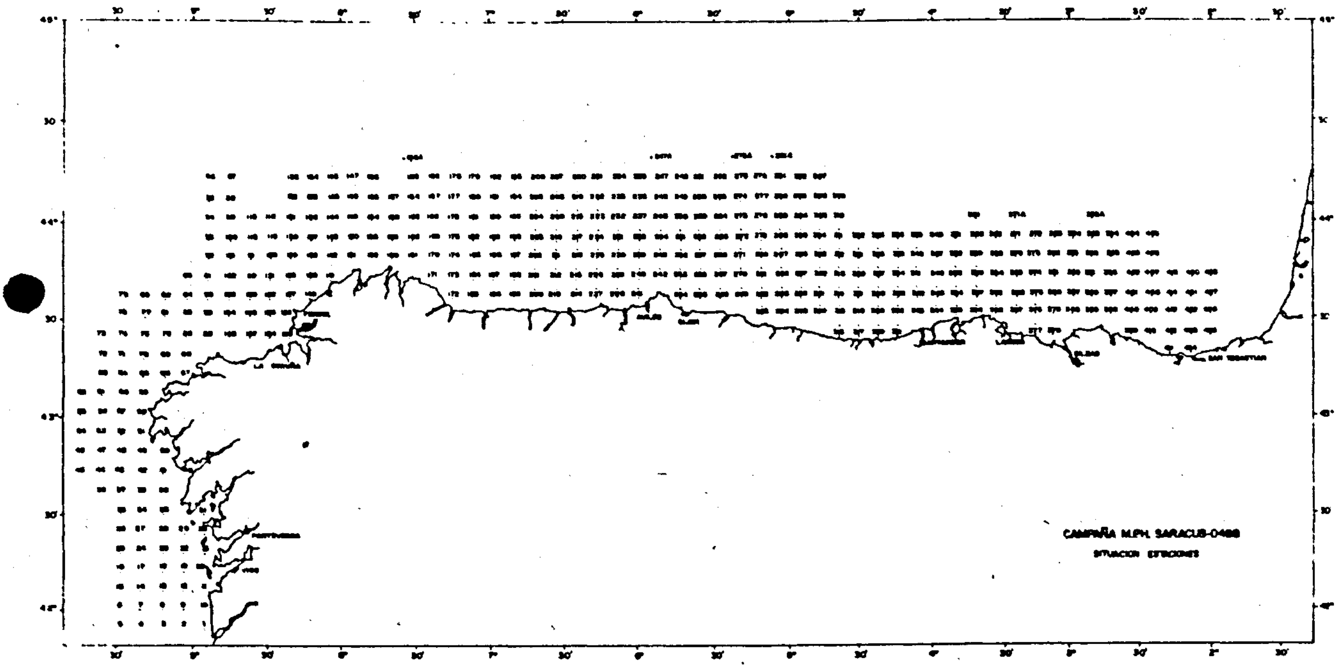

Fig. 1.- EPM Egg Survey.

A 6 by 6 mile grid was the basic plankton station scheme. Transects were spaced every six miles and acoustic tracking was carried out following the station numerical order. To achieve a better precision of the estimate of egg production, more plankton tows were allocated to the western and part of the eastern Cantabrian area where high spawning activity occurred. The 6 by 6 mile grid was modified to a 6 by 3, that is, adding up one station every 3 miles within the same transect. A total of 524 plankton stations were realized, that represent, a coverage of 51,736 km^2 of marine surface. Sardine eggs were present in 283 of the stations sampled.

Plankton samples were taken using a 25-cm diameter net of 150-micron mesh (Pairovet version, Smith et al., 1985) retrieved vertically from a depth of 100 mts. at a speed of aproximately 1 m/sec. Mean volume filtered was 5.09 m^3 with a standard deviation of 1.05 m^3.

In every station, surface temperature, wind speed and direction were recorded. These were complemented with CTD (77) and XBT (50) casts, which represent aproximately 25% of the stations sampled.

Adult sardine were sampled with an epi-pelagic trawl at 30 sampling stations out of 44 tows (Fig. 2). Three main problems have to be identified in the adult sampling survey: 1) difficult fishing operations in rocky areas of the northern Galician shelf, 2) inaccessibility to areas where fishing gear of fixed nature were installed (western and eastern Cantabric) and, 3) hydrated females have to be fished during daylight hours, when pilchards are most likely to avoid the net.

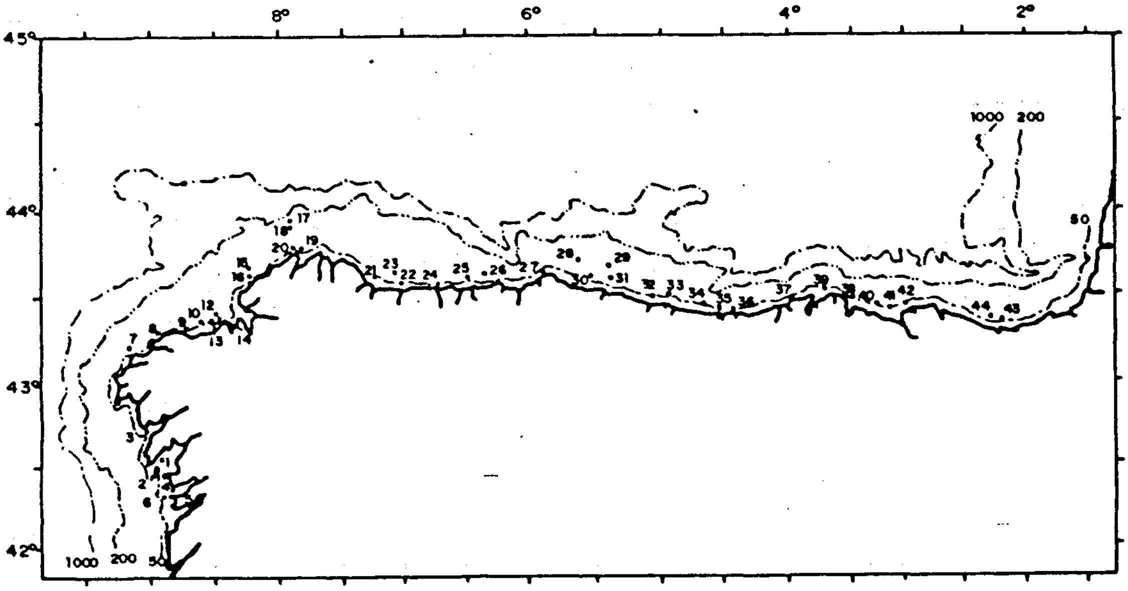

Fig. 2.- Adult trawl survey of EPM.

Egg production estimation model

The spawning biomass estimate is based on Parker's (1980) equation on biomass estimation that was modified by Stauffer and Picquelle (1980) for the northern anchovy, Engraulis mordax,

$$B = k\,A\,\frac{P_o\,W}{R\,F\,S}$$

where,

- B = spawning biomass in metric tons
- P_o= daily egg production (number of eggs per sampling unit, 0.05 m^2.
- W = average weight of mature females (grams)
- R = sex ratio (fraction mature of females by weight)
- F = batch fecundity (mean number of eggs per mature female per spawning)
- A = total survey area (in 0.05 m^2 sampling units).
- S = fraction of mature females spawning per day
- k = conversion factor from grams to metric tons.

The variance of the biomass estimate through this method is calculated through the delta method (Seber, 1973), as a function of variance and covariance of the estimates of parameters:

$$\mathrm{Var}\,(B) = B^2 \,*$$

$$\Big\{\frac{\mathrm{Var}(P_o)}{P_o^2} + \frac{\mathrm{Var}(W)}{W^2} + \frac{\mathrm{Var}(R)}{R^2} + \frac{\mathrm{Var}(F)}{F^2} + \frac{\mathrm{Var}(S)}{S^2} +$$

$$2\Big[\frac{\mathrm{Cov}(P_oW)}{P_oW} - \frac{\mathrm{Cov}(P_oR)}{P_oR} - \frac{\mathrm{Cov}(P_oF)}{P_oF} - \frac{\mathrm{Cov}(P_oS)}{P_oS} - \frac{\mathrm{Cov}(WR)}{WR} -$$

$$\frac{\mathrm{Cov}(WF)}{WF} - \frac{\mathrm{Cov}(WS)}{WS} + \frac{\mathrm{Cov}(RF)}{RF} + \frac{\mathrm{Cov}(RS)}{RS} + \frac{\mathrm{Cov}(FS)}{FS}\Big]\Big\}$$

The daily egg production of eggs in the survey area, P_oA, is based on the egg sampling and a temperature dependent model of the sardine egg developtmental rate, while the biological parameters of the adults are estimated from the adult sampling trawl survey.

RESULTS

Egg distribution pattern

Sardine fish egg distribution is shown in Fig. 3. No spawning activity is observed in the southernmost area of the Galician region. Spawning was first shown in the south of Cape Finisterre in the mouth of Ría de Arosa (transect line 31-35), and continued toward the northwest-east direction. Actually, the area of first egg catches coincided with the first adult catches, which contained the first samples of females with hydrated oocytes.

The distributional pattern indicate region differences which was taken into account in this study. In the Galician region, spawning areas of pilchard are restricted to the coastal areas, whereas, in the western and central part of the Cantabric (Asturian region) pilchard eggs are widespread; and in certain transects (between Avilés and Gijón), the spawning area was not encompassed with negative egg hauls. The eastern Cantabric, seems to show an intermediate situation, with a higher predominance of a more litoral type of distribution of pilchard eggs.

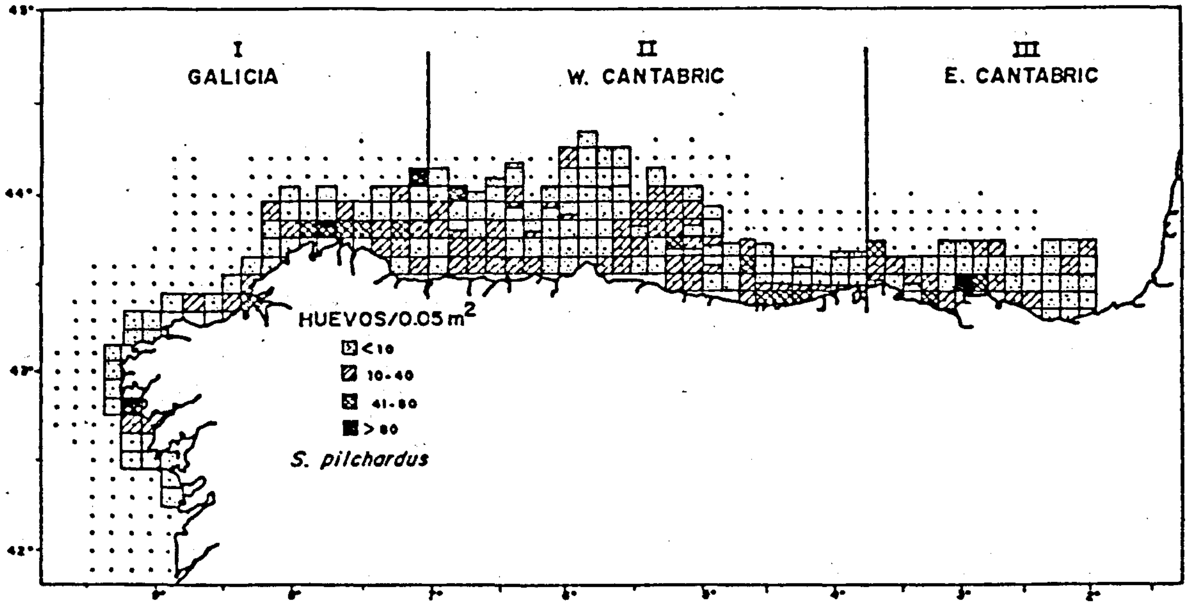

Fig. 3.- Pilchard egg abundances (eggs/0.05m^2) by regions. Shaded blocks represent the positive stratum (1).

Except where high egg abundances occurr in offshore areas, the western Cantabric; either the geographic distribution of adult fish schools observed by the sonar mappings or the adult sardine catches agree with the distribution of eggs.

Significant difference in the adult biological parameter estimates, difference in egg distributions and the pre-established acoustical divisions led us to a post-stratify the survey area into three regions (I, II and III) and the EPM spawning biomass estimate was obtained for each region.

Region I corresponds to the Galician area, extending from the south (41°55'N) to the north and a section of the western Cantabric (transect line 179-185).

Region II covers the western Cantabric where egg presence dominates most of this area covered. This region includes from transect line 186-192 to transect line 351-355.

The smallest region of the three corresponds to region III, which is the eastern Cantabric.

EPM Parameters Estimate

Daily Egg Production, P_o

The parameter P_oA, the daily production of eggs in the sea, is the total area multiplied by the number of eggs spawned per day, per unit area, averaged over the range and duration of the survey, or in this case, within each of the regions considered.

Positive plankton tows provide the sardine egg data and eggs were staged and aged. Egg production, P_o, is estimated by fitting an exponential mortality function to the data of eggs at age. Time-zero intercept of the fitted function is the estimate of egg production at spawning.

Following the sampling scheme used by Picquelle and Hewitt (1983) for northern anchovy, the total area was first determined by the sampled surfaces in terms of 6 by 6 nm grid. A 0.05m² sampling unit represents the center of this block. This sampling design assumes that the distribution of eggs within one block is independent of the distribution within the adjacent blocks. In the areas of expected spawning intensity, sampling intensity increased to a 6 x 3 nm grid. In order to compensate this uneven sampling intensity, each station was assigned a weighting factor, that is proportional to the area which the station represents.

Secondly, the stations were stratified by location in order to decrease variance. Many stations are located beyond the spawning range of pilchard. These contribute a large number of stations with 0 egg counts. To reduce their impact on variance, the total survey area is poststratified into two strata: stratum 0 contains the geographical area where no spawning occurrs (thus, daily egg production = 0) and stratum 1 accounts for the stations where positive egg counts occurr along with the few negative stations imbedded in this area. These two strata were created for each region (Fig. 3).

Their respective areas (km²) and the number of stations (n) comprising each stratum by region were as follows:

		Regions			
Stratum		Galicia I	W Cantabric II	E Cantabric III	Total
1	Area(km²)	6,915	13,829	5,680	26,424
	n	56	186	41	283
0	Area(km²)	15,188	6,668	3,457	25,313
	n	123	81	37	241
Total	Area	22,102	20,497	9,137	51,736
	n	179	267	78	524

Sardine eggs from each sample were counted and staged according to their degree of embryonic developtment. These were classified into 11 stages which were established by Gamulin and Hure (1955) complementing it with criteria from those described by Moser & Ahlstrom (1985) and Ahlstrom (1943). These stages of eggs were then aged.

The stage-to-age procedure was based on the results of a laboratory experiment, in which the induction-spawned eggs were incubated at five temperatures (11°C, 13°C, 15°C, 18°C and 20°C,) and the elapsed time were recorded (Miranda et al., 1989).

The analysis of the empirical data on the rate of developtment shows the best fit of developtment curves was the combination of an exponential and power function, described in Lo (1985).

The resulting equation was:

$$y_{i,t} = 17.515\ e^{-.13621(t)-.1734(i)}\ i^{2.222}$$

where,

$y_{i,t}$ corresponds to the average age of the egg at stage i and temperature t. It showed a very good fit; R^2 was 0.986.

Thus, for each of the 11 stages, the average age of sardine eggs can be estimated from the above equation for a given temperature.

The program STAGEAGE described in Hewitt et al. (1984) and in Lo (1985) was modified according to 1) a model for a temperature-dependent egg developtment, 2) the distribution of age within each stage, and 3) a daily peak spawning time (19:00 GMT), in order to acquire an automated ageing procedure.

The STAGEAGE, a FORTRAN program, was compiled to run on a PC compatible. It was modified and named SSTAGEAG with reference tables that allow the assignement of ages to the egg data set according to the station temperature and the time of tow. These reference tables were created assuming peak spawning time at 19:00H GMT, and thus measure the time elapsed between spawning and catch.

SSTAGEAGE outputs several data files (Lo, 1985), among which FOR038.DAT, gives the results of two variables, number of eggs and age in day categories, A, B, and C-day eggs. Thus, the data is tabulated by age for each station, with each one accounting up to three observations (one for each day category). This file was used directly for the regression estimates of egg production and egg mortality rates.

The exponential mortality model

$$P_t = P_o\, e^{-zt}$$

was then fit to the data using a weighted nonlinear least squares regression (Dixon and Brown, 1979), where

P_t = number of eggs per $0.05 m^2$ in age category t

t = age in days measured as the elapsed time from the spawning to the time of sampling

P_o= daily egg production per sampling unit ($0.05 m^2$)

z = daily rate of instantaneous mortality

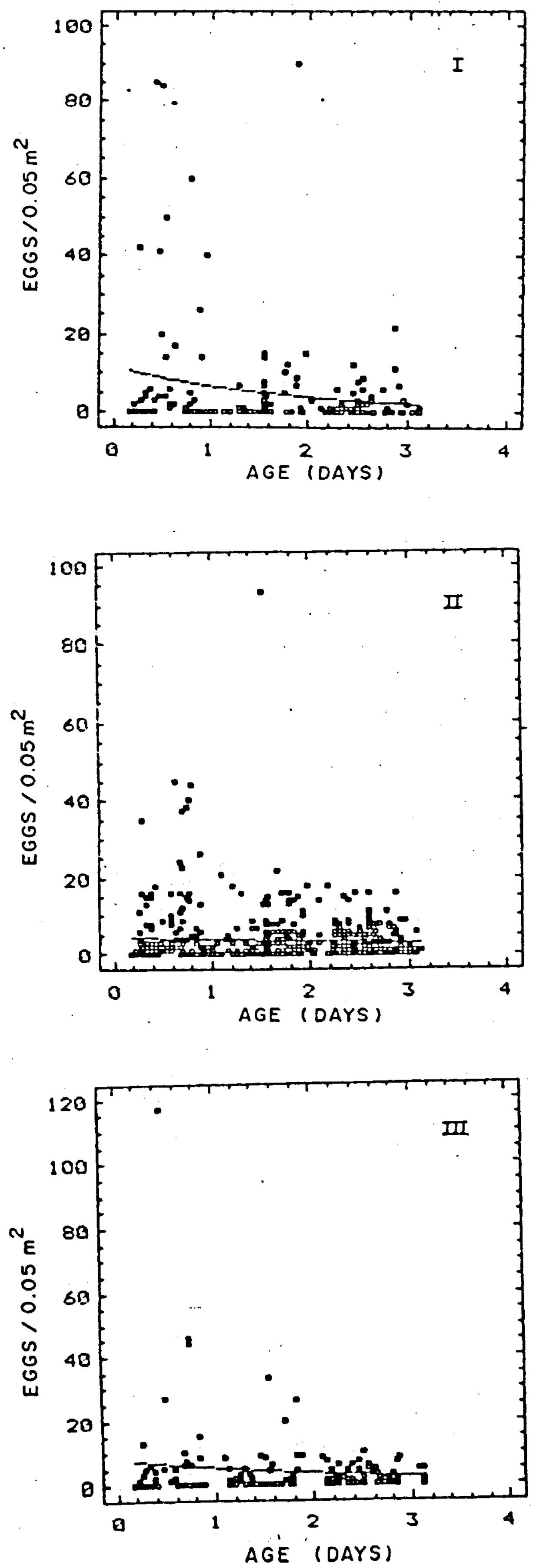

Fig. 4.- Exponential mortality model for estimating P_{01}, plotted with egg abundances for each region.

This model was fit to the data from stratum 1 for each of the three regions. In consequence, each region has an estimate of P_{01} (intercept) and a corresponding egg mortality, z (slope) (Fig.4).

The final stratified estimate of P_0 by regions was calculated as the weighted average of the two strata where the strata weights u_i are proportional to A_i, the area of the ith stratum and P_{00} is zero by definition, and the weights are the relative areas of the two strata, that is,

$$u_1 = \frac{A_1}{A_1 + A_0}$$

$$P_0 = u_1 P_{01} + u_0 P_{00} = u_1 P_{01}$$

and the variance, adjusted for the postsurvey stratification (Jessen, 1978), is

$$\mathrm{Var}(P_0) = (1 + 1/n)\,[(A_1/A)\,\mathrm{Var}(P_{01}) + (A_0/A)\mathrm{Var}(P_{00})]$$

where, A_i is the area of stratum i for each region,
n is the total number of observations by region,
$\mathrm{Var}(P_{01})$ is the estimated variance of stratum 1 for each region as calculated from the regression,
$\mathrm{Var}(P_{00})$ is zero by definition.

In summary, the results related with the estimates of P_{01} and P_0, for the three regions were:

	Galicia I	W Cant. II	E Cant. III
P_{01} (eggs/0.05m²)	11.52	4.29	7.08
Standard error	3.78	0.86	3.02
z (egg mortality)	0.55	0.062	0.38
Standard error	0.33	0.14	0.38
u_0	0.69	0.33	0.40
u_1	0.31	0.67	0.60
Mean Temperature(°C)	13.7	14.15	12.85
P_0 (eggs/0.05m²)	3.5712	2.8743	4.248
Standard error	2.1046	0.7039	2.3392

Region I has the highest egg densities, P_{01}, due to the high egg counts that ocurr in the northern coasts of Galicia and the westernmost coasts of the Cantabric region.

On the other hand, P_o in region I, drops to values similar to those produced in regions II and III, because in this region, 31% of the weighted areas accounts for the positive stratum, whereas in regions II and III, this relationship is over 60%. Intense spawning in the Galician area was confined to a rather small area in relation to the total surveyed area. These concentrated high egg densities resulted in high standard error of the estimate.

In contrast, in the western Cantabric (II), spawning has a widespread distribution and the resulting egg counts data set was much more homogeneous.

Adult Parameters

The adult parameters, W,F,S and R were estimated through the epi-pelagic trawl samples and the biological sampling of pilchard realized during the cruise.

For each of the parameters, mean and variance were estimated following Picquelle and Stauffer's (1985) procedure, calculating weighted averages since the number of sampled individuals are not equal in each of the tows, where

$$\bar{\bar{y}} = \sum_{i=1}^{n} m_i \bar{y}_i / \sum_{i=1}^{n} m_i \quad (1)$$

$$\hat{Var}(\bar{\bar{y}}) = \frac{\sum^{n} m_i^2 (\bar{y}_i - \bar{\bar{y}})^2}{\left(\sum_{i=1}^{n} \frac{m_i}{n}\right)^2 n(n-1)} \quad (2)$$

$\bar{\bar{y}}$= the estimate of the population mean
n= number of collections
$\bar{y}_i = \sum_{i=1}^{n} y_{ij}/m_i$ observed mean value in collection i
y_{ij} = observed value for the jth fish sampled and ith trawl
m_i= the number of fish subsampled from the ith catch

Average Female Weight, W

This parameter was calculated as the mean weight of mature females per trawl, using a maximum number of females as subsample target, that was 25 mature females per trawl and a total of 563 females. However, this number was not always reached, because either few fish were caught or most of the catch were inmature females.

In the estimation of this parameter, y_{ij} of equation (1) becomes W_{ij}, that is, the whole body weight of the jth mature female from the ith trawl. This observed weight has to be adjusted for those females which are in the hydrated condition, due to the water retention during hydration. This adjusted W_{ij} is estimated through a linear regression of whole body weight to ovary-free weight for females which had no hydrated oocytes.

The resulting linear regression is,

$$W = - 2.051 + 1.079W^{*}$$

where, W is the whole body weight of mature females and,
W* is the ovary-free weight of females with no hydrated eggs.

The following data on this parameter represents the average weight of mature females by regions with their corresponding coefficients of variation, showing a clear increase of this parameter in an eastward direction, in accordance with the differential distribution of the adults mentioned by Porteiro et al. (1986).

Ave. Female Weight	Galicia I	W Cant. II	E Cant. III
W (gr.)	64.93	79.34	86.31
c.v.	0.06	0.08	0.03

Batch Fecundity, F.

Hydrated females have been collected throughout the survey and the number of eggs per batch (F) have been the basic data set for this parameter. Batch fecundity was estimated by regressing batch fecundity (F) on ovary-free weight of those females which had hydrated oocytes (W*) and without post-ovulatory follicles, as shown through histological analysis, indicating that spawning has not begun.

A total of 126 females with hydrated oocytes, obtained from the EPM survey carried out by Spain and Portugal, were analyzed in order to have a higher number of ovaries for regression analysis, because there were no significant differences in the number of oocytes per gram of fish between specimens from Spain and Portugal (Pérez et al., 1989).

A weighted linear regression was used to estimate batch fecundity of all the mature females up to maximum number of 25 per catch.

The resulting linear regression was,

$$F = -1260.8 + 444.43W^{*}$$

The average batch fecundity was calculated from equation (1), but in this case, variance is estimated as described in Draper & Smith (1966), where,

$$Var(\bar{\bar{F}}) = \frac{\sum_{i=1}^{n} m_i^2 \frac{(\bar{F}_i - \bar{\bar{F}})^2}{n-1} + \frac{S_h^2}{n} + (\bar{W}_i - \bar{W}_n)\,\hat{Var}(\hat{\beta})}{\left(\sum_{i=1}^{n} m_i/n\right)^2 n},$$

where, $\bar{\bar{F}}$ = the estimate of batch fecundity for the whole population of mature females,
$\bar{F}_i$= the average batch fecundity,
S_h^2= the variance about the regression,

n_h = the number of hydrated females used in the regression
$\bar{W}_i$ = average ovary-free weight for the ith trawl,
$\bar{W}_h$ = average ovary-free weight for the n_h hydrated females,
$\hat{Var}(\hat{\beta})$ = the variance of the slope of the regression.

The results of the analysis of this parameter were,

Batch fecundity	Galicia I	W Cant. II	E Cant. III
F	2727.48	33801.8	33910.7
c.v.	0.06	0.09	0.03

Because batch fecundity is high for larger females, it is expected to observe higher batch fecundity in eastern regions: regions II and III.

Spawning fraction, S

This parameter represents the fraction of mature females that have spawned per day.

The analysis of the histological age-structure of post-ovulatory follicles has revealed the existence of 4 ages, because the degeneration of follicles in pilchard has been shown to be very slow; and therefore, follicles are clearly differentiated with ages reaching 80 hours. Females from 0 to 6 hours have been classified as day-0, from 18 to 30 hours as day-1, from 42 to 54 as day-2 and finally as day-3, those follicles with ages over 60 hours.

The term y_{ij} of equation (1) here is equal to the average proportion of mature females in the ith trawl which have day-1 and day-2 post-ovulatory follicles. Day-2 post-ovulatory follicles have been included in the the estimate since the degeneration of follicles in pilchard is very slow.

Day-3 follicles have not been used in equation (1), because this age group presents more age reading difficulties.

There has been an oversampling of follicles under 18 hours (day-0), thereby, causing a bias in the calculation of the spawning fraction. In this manner, the total number of mature females has been calculated following the expression,

$$m_i = \frac{\text{Day-1} + \text{Day-2} + \text{Day-3}}{3} + \text{Day-1} + \text{Day-2} + \text{Day-3} + \text{Mature Females}$$

in which each term represents the number of females in a particular age of post-ovulatory follicles.

The following table shows the spawning fraction values by the different post-ovulatory follicles ages by the different regions and their respective coefficients of variation.

It's interesting to remark also how coefficient of variation in relation with the spawning fraction increases as we use the post-ovulatory follicles of day 1 or day 2, instead of their mean value.

Age follicle	Galicia I	W Cantabric II	E Cantabric III
Day-0	0.64	0.15	0.10
c.v.	0.58	0.68	0.47
Day-1	0.04	0.09	0.23
c.v.	0.55	0.24	0.20
Day-2	0.11	0.17	0.19
c.v.	0.24	0.22	0.20
Day-3	0.05	0.23	0.13
c.v.	0.60	0.14	0.23
Day-1 + D-2	0.08	0.13	0.21
c.v.	0.20	0.11	0.13

The values of spawning fraction by regions also show an increasing trend towards the east, indicating a higher spawning frequency in the older females.

Spawning fract.	Galicia I	W Cant. II	E Cant. III
S	0.08	0.13	0.21
c.v.	0.20	0.11	0.13

The low spawning fraction value produced in region I (0.08) contrasts with the high value that would be attained if this were calculated by the day-0 post-ovulatory follicles. A decrease in the coefficient of variation is observed when spawning fraction is estimated through the mean of post-ovulatory follicles of ages 1 and 2.

Sex ratio, R

This parameter was calculated as the fraction in weight of mature females of the population. The equation used is also (1), but in this case, m_i is the weight of the subsample instead of the number of fish and y_i is the fraction of the weight of the subsample that correspond to female fish.

Mature specimens and inmature ones were included in the analysis. The maximum number of specimens per trawl were 50, from which only the weights of the first 10 males and 25 females were measured.

The total weight for each sex is obtained from Picquelle & Stauffer (1985), where

$$m_i = W_i^F + W_i^M$$

m_i is the weight of the subsample,
W_i^F is the total estimated female weight and,
W_i^M is the total estimated male weight,
and y_i is the estimated total weight divided by m_i,

$$y_i = W_i/m_i$$

The results of the estimates of this parameter were:

Sex ratio	Galicia I	W Cant. II	E Cant. III
R	0.35	0.65	0.66
c.v.	0.12	0.10	0.08

Region I registers low sex ratio values, whereas, regions II and II records estimates over 50%. If sex ratio were calculated for the entire survey area, this would be 55%.

Biomass Estimate

All the required parameters for the estimation of the spawning biomass are summarized in the following table. The biomass estimates of each region were calculated by the egg production estimation equation and the variances were calculated using the delta method (Seber, 1973).

Parameters	Galicia I	W Cant. II	E Cant. III	
P_o	3.57	2.87	4.25	
c.v.	0.59	0.25	0.55	
A(in 0.05m²)	$4.420x10^{11}$	$4.099x10^{11}$	$1.827x10^{11}$	
W (grm.)	64.93	79.34	86.31	
c.v.	0.06	0.08	0.03	
F	2727.48	33801.8	33910.7	
c.v.	0.06	0.09	0.03	
S	0.08	0.13	0.21	
c.v.	0.20	0.11	0.13	
R	0.35	0.65	0.66	
c.v.	0.12	0.10	0.08	
				TOTAL
Biomass(B)	134,195	33,503	12,467	180,165
c.v.	0.66	0.30	0.56	0.50

The sample covariances were calculated for the adult parameters, since P_o was derived from the plankton survey, whereas the adult parameters were derived from the trawl survey. Thus the sample covariance between P_o and the adult parameters was assumed to be 0.

The sample covariances calculated for the adult parameters were,

Sample covariance	Galicia I	W Cant. II	E Cant. III
COV (WR)	0.01227	0.142	0.0719
COV (WF)	5833.1	17783.2	2047.1
COV (WS)	0.0156	0.0276	-0.0408
COV (RF)	5.484	63:162	30.076
COV (RS)	0.00029	0.00024	-0.000469
COV (SF)	7.0029	12.31	-17.818

DISCUSSION

The EPM assumes that the parameters in the model are constant over the range and duration of the survey. Since this assumption does not occurr in the presented paper, the spawning biomass of the Galician and Cantabrian pilchard has been evaluated by regions.

One of the most clear differentiation was observed in the mean weight of mature females. An increment towards the east of this parameter is very clear; and it has been demonstrated by Porteiro et al. (1986) that the oldest age classes of pilchard (over 5 years old) mainly reside in the eastern sector of the Cantabrian coast. Different age composition of adult fish affects other parameters, such as, batch fecundity, in which in the distributional areas of the young age-classes (Galicia) is quite lower.

In the case of sex ratio, the differences between regions are quite pronounced. In Galicia (I), this value is 0.35, in contrast to the two other established regions, where there is a clear predominance of females in the population. Different fishing hours by regions and/or different behaviour by sexes of pilchard may ultimately alter the number of females in the different areas. However, no clear relation exists between the fraction of reproductive females and trawl time for any of the three regions (Fig. 5).

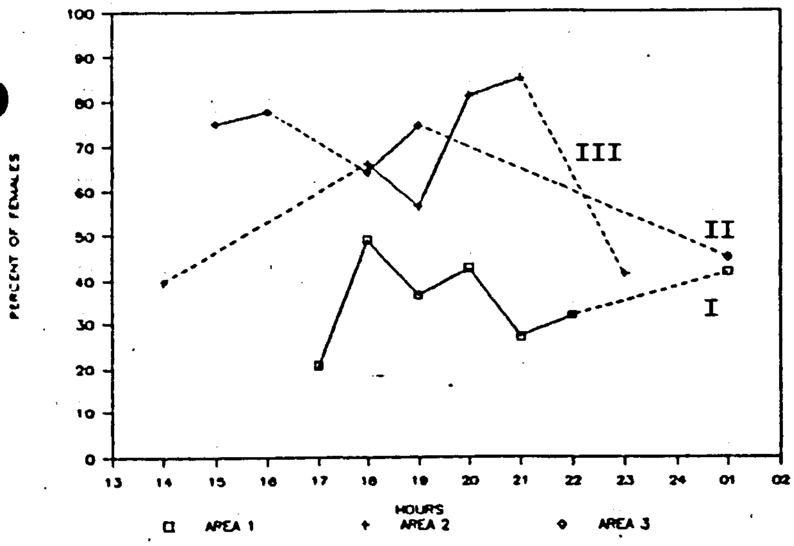

Fig. 5.- Proportion of females by hours and regions.

One possible explanation of this phenomenom would be that in region I, pilchards were close to spawning time or that at this moment they were more vulnerable to the fishing gear (since, at this moment there was a greater concentration), than those which were farther off to non-spawning time. Moreover, this would explain a low spawning fraction value in region I calculated with post-ovulatory follicles of ages 1 and 2, with the abundance of hydrated females and with post-ovulatory follicles of day-0 (Fig. 6).

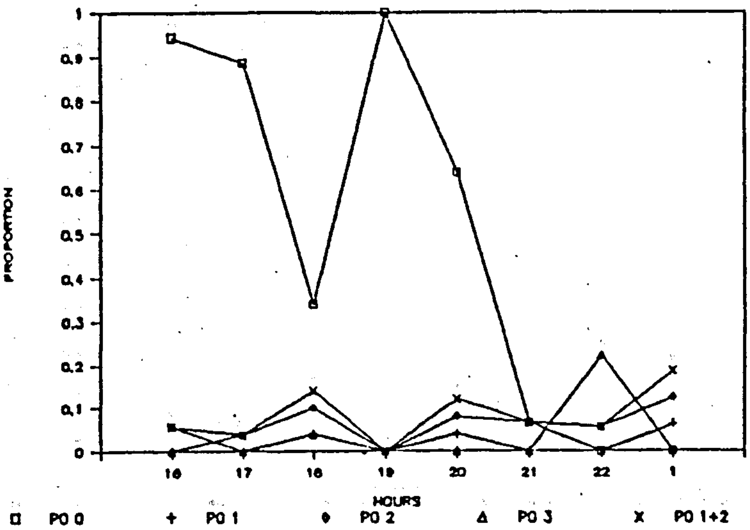

Fig. 6.- Proportion of different ages of post-ovulatory follicles (region I).

Comparing the biomass estimate by EPM with the acoustic evaluation, there is a difference in the total biomass of aproximately 110,000 MT. Porteiro (personal communication) had estimated by acoustics in 159,691MT for region I, 103,816MT for region II and 30,786MT for region III. Although, this differences appears remarkable, it is not surprising, when we take into consideration the coefficient of variation of the spawning biomass estimate and the acoustic method relies mainly on its estimates on the precision of the applied target strength.

Although the compared estimates are different between EPM and acoustics, the general trend among regions is similar: an increment of biomass from east to west. In the adult parameters between the two methods there is concordance. For example, the acoustic sampling show that region I has the principal proportion of the age classes 0 and 1 and the EPM indicate that in this region, batch fecundity, average female weight and spawning fraction were lowest. In the eastern sectors, a greater representation of the older age classes from the acoustics survey was reflected by the estimate of the adult parameters.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the Joint U.S.-Spain Committee for Scientific and Technological Cooperation, without its support the Iberic SARP would not have been possible, and especially to the following persons who have contributed to the initiation and assesment of this project; Dr. Paul Smith, Dr. Jurgen Alheit, Carmela Porteiro and M. Emília Cunha.

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